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WASATCH NATIONAL FOREST

ALTA AVALANCHE STUDY CENTER

Miscellaneous Report No 2

THREE INSTRUMENTS USED IN AVALANCHE HAZARD FORECASTING:

1. SNOW SETTLEMENT - TEMPERATURE
2. SNOW COLLECTOR FOR RECORDING RAIN GAUGE
3. TEMPERATURE TELEMETER

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Introduction

Two of the instruments described in this report have been in use for a number of years at Forest Service avalanche stations. The third, the temperature telemeter, was installed and tested at Squaw Valley during the winter of 1960-61, and seems to work very satisfactorily with the tests so far. Purpose of this report is to provide a short description of these instruments and furnish sufficient technical data that they may be duplicated when needed at future stations yet to be established. It is not the intent here to make a full analysis of their behavior or discuss similar instruments reported in the literature. We do acknowledge the settlement gauge to be based, with some modifications, on the one originated at the Weissfluhjoch in Switzerland over twenty years ago. The snow collector is an original and strictly empirical design, justifying its continued existence by the fact that it works rather well for the limited purpose for which it was intended. The temperature telemeter uses standard circuitry, and is unique only in this application.

Further details may be obtained from the Alta Avalanche Study Center.

Settlement-Temperature Gauge

This instrument has been in use for a number of years at Alta, Stevens Pass and Squaw Valley. It provides a simple and reliable means of measuring snow cover settlement throughout the winter without disturbing the snow cover. A simple adaptation, shown in the schematic diagram, permits observation of snow temperatures as well.

The settlement gauge is nothing more than a Wheatstone bridge, the vertical resistance wire forming one side of the bridge and the helix potentiometer the other. The resistance wire, #20 to #24-gauge nichrome, is suspended vertically in the center of a smooth, level area in the study plot, and is long enough to clear the maximum winter snow depth. Following each snowfall, a wooden lattice supporting a crocodile clip connector is placed on the snow surface and the clip attached to the resistance wire. A connecting lead runs from the slip to junction box. The lattice may be constructed of stripes of lath, 18 to 24 inches long, nailed together and painted white. As the lattice becomes buried under subsequent snowfalls, settlement carries it downward and the clip slides along the resistance wire. Its buried position at any time may be determined by connecting the test set and balancing the bridge, as indicated by zero-reading on the galvanometer (G). Comparison of the helix potentiometer dial reading with a previously determined calibration chart locates the height of the clip and lattice above the ground in terms of inches or centimeters.

A modification at Stevens Pass uses sliding contacts permanently attached to the resistance wire. The clips are connected to these instead of to the wire itself.

The lattice with clip and lead wire may be stored inside until required. The lead wire is then uncoiled and attached to a terminal strip in the junction box, while the lattice is clipped to the resistance wire. When making the latter

connection, care should be taken not to disturb the snow around the wire and plates, especially by walking too near them in soft snow.

The 100-ohm helix potentiometer used is a ten turn Borg Micropot with associated ten-turn dial reading from 000 to 999. Galvanometer shunt resistor R_1 should be one-tenth of the internal meter resistance or less.

A 2-cell flashlight bulb connected in series with the battery (not shown in the diagram) will reduce the heavy current drain by the resistance wire and prolong battery life.

The Wheatstone bridge of the settlement gauge may readily be adapted to the measurement of snow temperature, with thermistors as sensing elements. Thermistors are semi-conductor elements with a large negative temperature coefficient of resistivity. This rapid change of electrical resistance with temperature can easily be measured with the settlement test set.

The circuit modifications for temperature measurement are illustrated in the schematic diagram. The side of the bridge represented by the resistance wire in the settlement measurements is replaced electrically by two separate elements, the thermistor and a resistor (R_2) whose value is approximately equal to the thermistor resistance at 0° C. This latter value is close to 3000 ohms for the Fenwall Type G378 thermistor currently in use.

A thermistor is attached by short (2-3 ft) lead wires to each settlement plate, and placed on the snow surface adjacent to the plate. The measured plate position thus indicates thermistor position, and permits calculation of temperature gradients in the snow cover. One lead from the thermistor is connected to the settlement plate clip wire, and the other lead is connected by a separate, parallel wire to a separate terminal strip in the junction box.

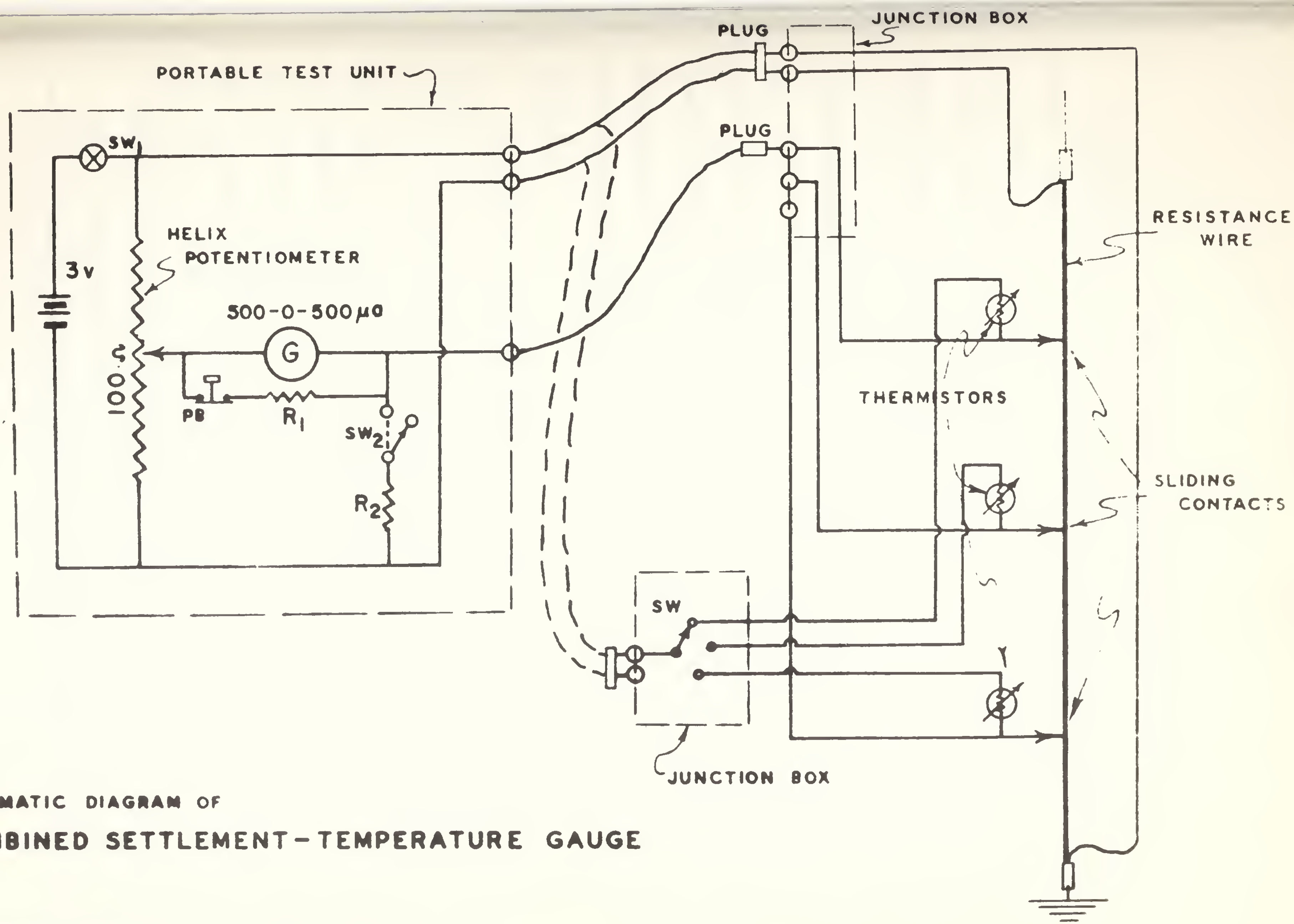
After the settlement plate positions are read, the test set connecting plug is shifted to the temperature circuit, as shown in the diagram, and SW_2 is then thrown to the temperature (closed) position. The bridge is balanced for each successive thermistor as it is connected by plug and switch, and the dial readings noted. These are later compared with the thermistor calibration curves to determine snow temperatures.

The thermistors must be individually calibrated prior to installation. Although their temperature-resistance curves are very similar, enough variation exists from one thermistor to another that a separate curve must be obtained for each one. Thermistor resistance is a non-linear function of temperature. When the Wheatstone bridge is connected in the fashion shown, dial readings are also a non-linear function of measured resistance. In this case the non-linearity feature tends to cancel with the result that dial readings are almost a straight-line function of temperature over the range of 0° to -15° C. commonly found in the snow cover.

After the thermistors have been attached to their lead wires, they must be coated with an insulating material. This affords protection from weathering in the field, and provides electrical insulation in the calibrating bath. Encapsulation in RTV silicone rubber is the best form of coating, but repeated coatings with white acrylic plastic spray enamel is satisfactory. Once the thermistors have been coated, they can all be placed as bundle in the calibrating bath and the lead wires brought out for convenient connection to the test set. A wide-mouth thermos bottle filled with an ice-salt or ice-alcohol mixture will provide a satisfactory calibrating bath. The calibrating standard may be a glass or a

dial thermometer inserted in the bath. The latter is more convenient. The temperature of the bath is successively adjusted to different values within the expected operating range by addition of ice, water, or freezing point depressant as required. After the bath has achieved equilibrium at each new temperature, the corresponding dial reading of the test set for each thermistor is recorded. From the record thus obtained a calibration curve can be constructed for each thermistor.

Occasional erratic operation of the settlement gauge has been noted, appearing in the form of anomalies, or "bumps" in the settlement curves of several centimeters magnitude. Calculations show that it is possible for these errors to be introduced by thermoelectric potentials generated at the copper-nichrome contacts when air and snow temperature differ widely. At the Alta installation, magnitude of this thermoelectric effect has been reduced by placing at 50 ohm resistor in series with the galvanometer, without seriously reducing meter sensitivity.



SCHEMATIC DIAGRAM OF

COMBINED SETTLEMENT-TEMPERATURE GAUGE

— SHOWN CONNECTED TO READ SETTLEMENT

— DOTTED LINES SHOW CONNECTION FOR TEMPERATURE

— THERE ARE ACTUALLY TEN SLIDING CONTACTS AND THERMISTORS

Snow Collector for Recording Rain Gauge

The measurement of snowfall or precipitation with an exposed precipitation gauge is difficult under the most favorable circumstances, and especially so in mountainous terrain where wind action is strong, for the amount of snow which actually falls into the orifice of the gauge seldom bears much relation to the average amount deposited on the ground. It is under just these most difficult conditions of windy storms in the mountains that the precipitation record is of most interest to avalanche forecasting. Several methods have been tested of controlling snowfall into a recording precipitation gauge in order to obtain a chart record of precipitation intensity during snowstorms. These include such standard methods as the use of wind shields around the gauge orifice. By and large these have been found unsatisfactory. The snow collector described here, while rather unorthodox in design, has stood well the test of use over a number of years.

The mountain observer readily notes that with any appreciable wind, the snow during a storm "falls" more horizontally than vertically. With winds above the critical level for avalanche formation (around 15 mph), the horizontal motion of a snow particle in the air greatly exceeds the vertical motion. Since these circumstances are the ones of interest to avalanche formation, a useful snow gauge may be adapted to collect the horizontal rather than the vertical component of snowfall. The snow collector described here thus bears some family resemblance to the vectopluviometer which has been tested for measurement of mountain precipitation in California. It has, however, two peculiarities of its own. Only a single inlet orifice is used, and this is kept directed into the wind by a wind vane which swings the pivoted collector. Though a simple

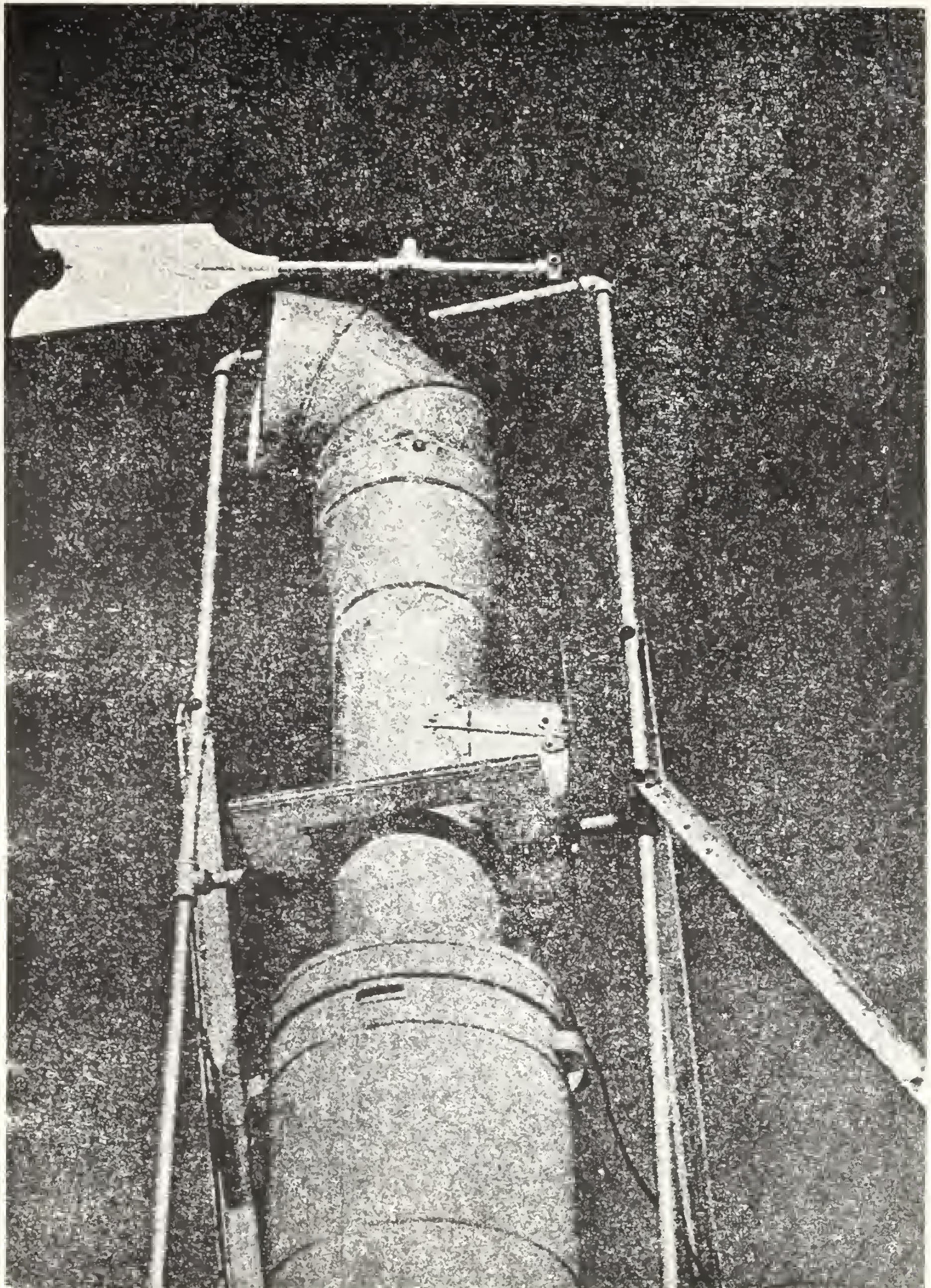
elbow might at first glance seem to serve better to direct snow into the gauge, this leads to some difficulties in also directing the force of the wind against the collection bucket and causing an undesirable amount of "pumping" of the recording pen arm. Furthermore, this type does not seem to provide uniform snow collection. The collector pictured in the accompanying sketch and photo circumvents these difficulties by providing an exhaust orifice for the wind. By increasing the wind channel diameter between inlet and exhaust, at the same time directing the air flow upward, a chance is afforded the wind-borne snow to fall into the recording gauge in a relatively undisturbed fashion.

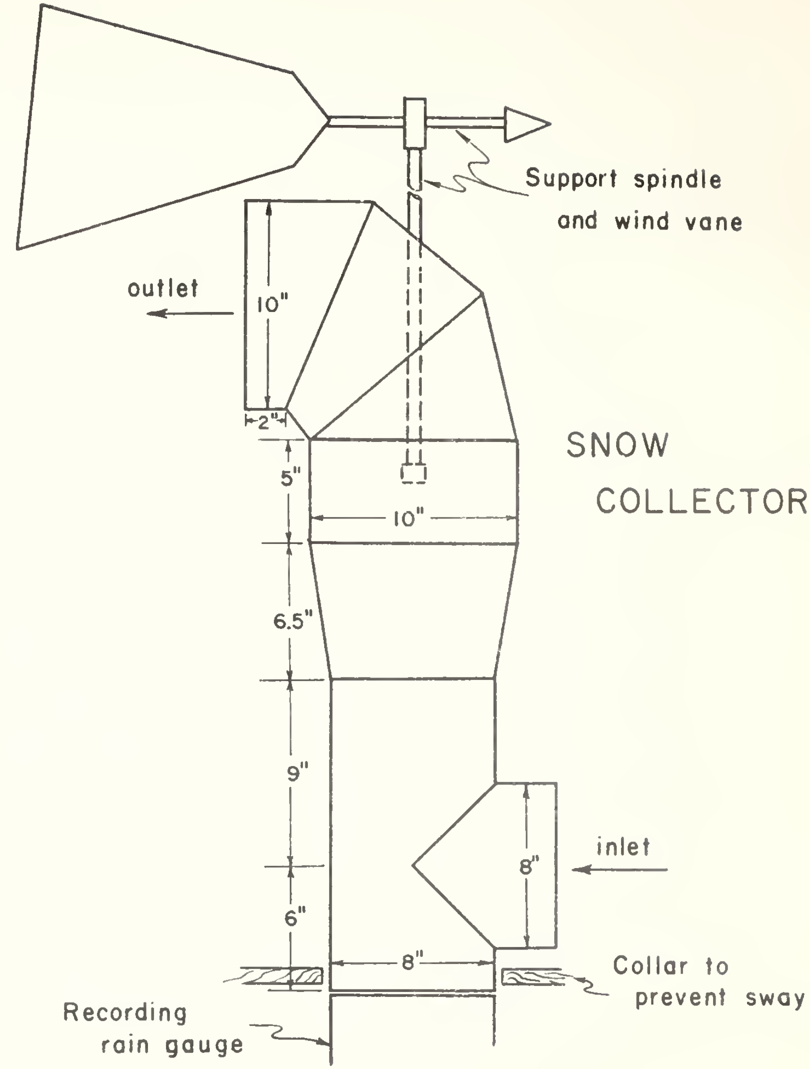
The collector is fabricated from standard galvanized sheet metal heating duct elements, and can easily be duplicated by a sheet metal shop. The support frame must be rigid, but offer minimum interference to snow collection. The pipe frame illustrated is recommended as sturdy and simple to assemble from standard pipe parts.

With the full eight-inch diameter of the inlet exposed, this collector gathers into the gauge over twice as much as snow as accumulates on an adjacent snow stake platform on the ground. It, therefore, has been necessary to mask the inlet with a diaphragm until the inlet cross-section has an area of about 28 square inches. This value was achieved empirically by adjusting the inlet area until a consistent match was obtained with snowfall on the ground. A good correlation was found in the collected snow in the gauge and that deposited on the ground over ranges of wind speed from 5 to 25 mph. Too few reliable data are available for determining the correlation at higher wind speeds. At very low wind speeds the collector, of course, gathers very little snow into the gauge, but these conditions are of lesser interest to avalanche forecasting.

During a heavy snowstorm, sufficient snow collects in the gauge to swamp it if not melted. This can be countered to some extent by charging the gauge bucket with calcium chloride or other anti-freeze, but this is not adequate to melt all the snow if precipitation is heavy. An artificial supply of heat must be furnished to insure complete melting of collected snow and proper functioning of the gauge. One method of heating that has been used successfully is the suspension (within the gauge bucket) of an electrical "heat tape" of the type used to prevent water pipe freezing. This delivers heat directly to where it is needed--in the bucket--but care must be taken to suspend the tape on a light aluminum frame from the gauge body, not from the bucket, so there is no interference with the bucket weighing. More recently, the gauge, in use at Alta, has simply utilized a 150-watt light bulb mounted in the bottom of the gauge next to the recording drum. This provides sufficient heat to the bucket under all but the most severe conditions.

Insurance of proper gauge operation in the absence of electric power is difficult. Theoretically, a propane pilot flame in place of the light bulb, described above, ought to provide adequate heat. In practice, it is found that it does while lit, but is very difficult to keep from blowing out during high winds even though several different types of burners have been tested. The high altitude at which these gauges were operated (8,500 to 11,000 ft.) probably accounts in part for the difficulty of maintaining reliable combustion.





SNOW COLLECTOR

Temperature Telemeter

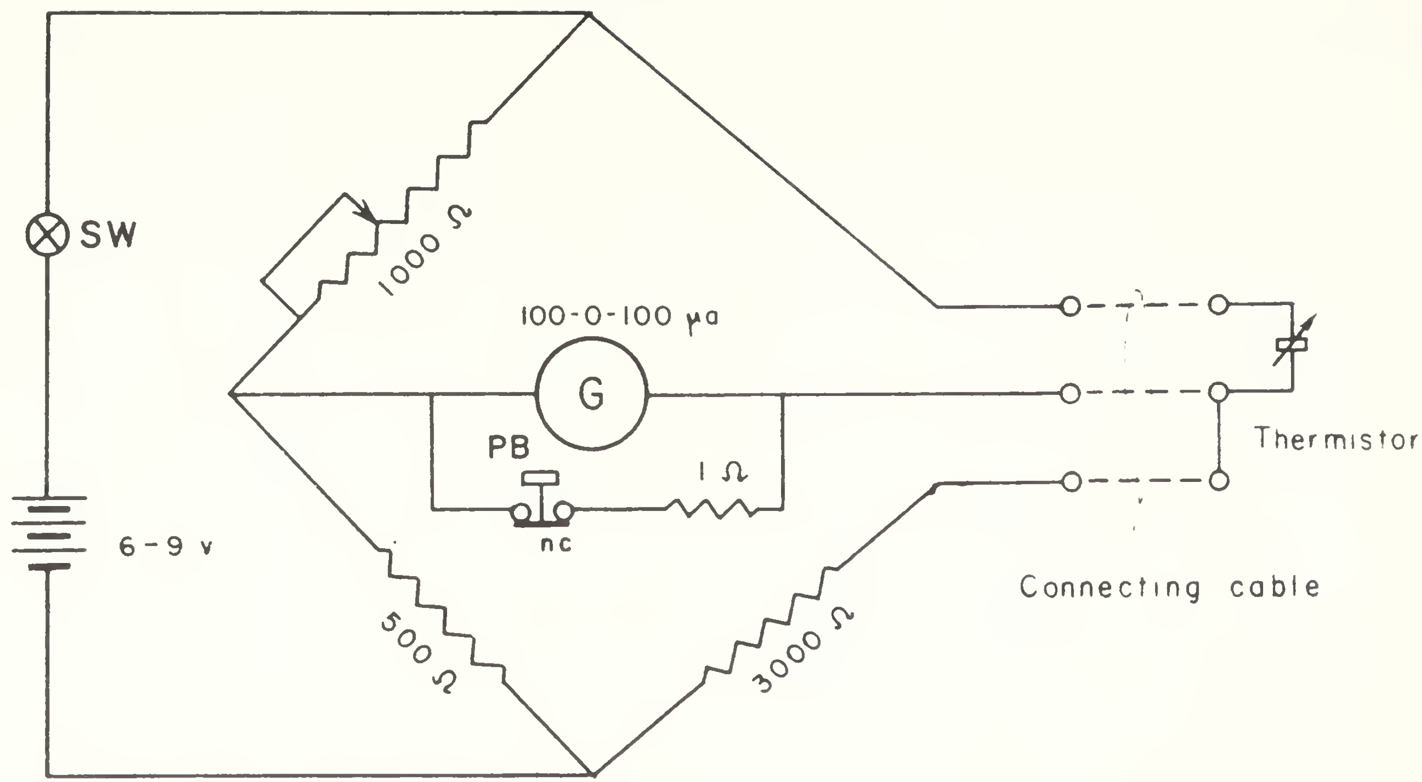
This instrument permits direct reading of air or snow temperature at long distances from the observation point. It was developed for observing air temperature in Squaw Peak Bowl, high above the regular snow observation station on the Squaw Valley floor, but may be extended to any application where a single temperature must be measured at a distance.

In essence, a simple Wheatstone bridge is used to read the resistance of a thermistor exposed in whatever temperature environment must be monitored. The Fenwall G378 thermistor is the same one used in the settlement-temperature gauge, and the circuitry is similar, with a more sensitive galvonometer substituted for greater precision, along with a higher-resistance Micropot. See schematic diagram. A three-wire circuit between bridge and thermistor is required to cancel out temperature variations of resistance in the cable, which would introduce substantial errors if only two wires were used. If the connecting cable is sound, and free of bad joints or leaks to ground, the distance at which the thermistor can be located is theoretically limited only by effects of cable resistance on bridge sensitivity. The cable length at Squaw Valley is approximately three miles, and operation has been satisfactory. Any effects, such as deterioration of poorly soldered joints or intrusion of water, which cause cable resistance or circuit insulation to change, will adversely affect instrument calibration.

The thermistor must be coated for protection and calibrated against a thermometer in the same manner as those used for snow temperatures. The calibration curve of dial readings versus temperature will in this case be distinctly non-linear, but the scale is sufficiently expanded to permit readings to the nearest 0.5° F., or even closer.

For measurement of air temperature, the thermistor should be exposed with the same care as a thermometer to avoid radiation errors. Exposure in a standard Weather Bureau instrument shelter, or similar shielded and ventilated enclosure, is recommended.

Thermistors tend to be unstable, and their calibration must occasionally be rechecked to insure accurate temperature measurements in any application. Any given unit may give good service for a long time, but there is no way of anticipating which ones are apt to suffer sudden alterations in characteristics. Those exposed to the open weather are more apt to alter than ones buried in the snow or ground. Recalibration at least once a year is recommended.



Schematic diagram of

TEMPERATURE TELEMETER